Technical Report 2004-03

PUGET SOUND NEARSHORE PARTNERSHIP

RESTORING OUR ECOSYSTEM HEALTH

Guiding Restoration Principles

Prepared in support of the Puget Sound Nearshore Partnership (PSNP)

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To develop an effective, large-scale ecosystem restoration program for the Puget Sound nearshore the Nearshore Science Team has developed a list of guiding restoration principles and fundamental ecological concepts and assumptions. These principles are considered critical to the success of diverse restoration and protection actions. They communicate our understanding of nearshore ecosystems and provide a framework for identifying, evaluating, and implementing restoration and protection actions. Developed to inform the Nearshore Partnership, it is anticipated that these principles will also be useful to the diverse array of people and organizations involved in restoration and protection of nearshore ecosystems and habitats.

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Cover: Spencer Spit on Lopez Island, Washington, is an example of a back-barrier lagoon. Courtesy of Hugh Shipman, Washington Department of Ecology.

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Executive Summary

To develop an effective, large-scale ecosystem restoration program for the Puget Sound nearshore—defined as shallow-water environments of estuaries and nearshore marine shorelines—the Nearshore Science Team (NST) of the Puget Sound Nearshore Partnership (PSNP) has developed a list of guiding restoration principles (GRPs) and fundamental ecological concepts and assumptions. These principles are considered critical to the success of diverse restoration and protection actions. They communicate PSNP's understanding of nearshore ecosystems and provide a framework for identifying, evaluating, and implementing restoration and protection actions; they apply to project stages from early planning to post-implementation monitoring. Developed to inform PSNP, it is anticipated that these principles will also be useful to the diverse array of people and organizations involved in restoration and protection of nearshore ecosystems and habitats. This document should be viewed in concert with three other important PSNP products: the guidance document (Fresh et al. 2004), the conceptual model (Simenstad et al. 2004), and the lessons learned document (Van Cleve et al. 2004).

This document is consists of four main parts: the underlying *scientific concepts and assumptions* upon which the scientific program is organized; the *guiding restoration principles*—the framework for a comprehensive, strategic planning process to guide program development and selection of restoration projects in Puget Sound; and the principles and elements essential for *adaptive management* and *monitoring* of restoration projects. These principles, concepts, and assumptions should be understood as a whole to ensure successful program implementation.

Fundamental Concepts and Assumptions

The following underlying scientific concepts and assumptions are derived from the current scientific literature that describes the natural structure and dynamics of estuarine and marine nearshore ecosystems and how we think they will respond to restoration actions.

Emergent Properties of Estuarine–Nearshore Ecosystems

1. Physicochemical processes play a very strong role in organizing and regulating estuarine nearshore ecosystems.
2. The structure of ecosystems is both the consequence of and a factor in the action of ecosystem processes.
3. Viewing estuarine–nearshore ecosystems in a hierarchical context is important to understanding ecological interactions and processes across different scales in time and space.
4. Natural disturbance regimes sustain the structure and functions of nearshore ecosystems.

Importance of Landscape Setting and Structure

1. Ecosystem function and performance are contingent upon landscape setting.
2. Nearshore ecosystem functions are explainable using concepts from landscape ecology.

Role of Population Ecology and Life-History Diversity

1. Spatial and temporal dynamics of animal and plant metapopulations are dependent upon the integrity of nearshore landscapes.
2. Landscape structure is an important factor sustaining life-history diversity within and among populations vulnerable to stochastic ecosystem change.

Guiding Restoration Principles

We developed the following guiding restoration principles to apply our understanding of the fundamental scientific concepts. These principles draw on ecological restoration literature relevant to the nearshore and on lessons of previous restoration efforts. Thus, they are intended to provide practical guidance for restoration program development.

Strategic

1. Programs should focus on restoration of natural processes that create and maintain nearshore ecosystem structure and function.
2. Program efforts should promote protection of nearshore habitats and the processes that sustain them.
3. Outreach and education should be incorporated into all parts of the program.
4. Program efforts must include social, cultural, and economic values at multiple scales in time and space.

Restoration Design

1. Restoration actions should be based on explicitly stated hypotheses.
2. Initial restoration projects should be designed as experiments to address information needs.
3. Project implementation should be preceded by restoration planning.
4. Restoration must consider "ecological succession."
5. Project proponents should recognize the limits on ecosystem potential constrained or limited by irreversible change.
6. Restoration projects should be based on carefully developed goals and objectives.

Project Follow-through

1. Project objectives should be used to build performance standards and implement a monitoring program that evaluates attributes directly related to these standards and the objectives they assess.
2. Adaptive management should be employed in project development and in revising program goals and objectives.

3. Project proponents should take advantage of best interdisciplinary science and technical knowledge and employ a scientific, peer-review process.
4. Analysis of ecosystem processes requires that data represent the spatial and temporal dynamics at various scales as well as being well documented and well defined.

Adaptive Management Principles

Because of the large amount of uncertainty associated with restoration of nearshore ecosystems, a program goal is to develop an adaptive management and monitoring plan designed to advance our understanding of relationships between ecosystem processes, structure, and functions.

Adaptive management entails using research and monitoring to allow certain projects and activities to proceed despite some uncertainty and risk regarding their consequences. The overall intent of this process is to reduce the risk and uncertainty associated with future actions. The adaptive management principles are as follows:

1. Adaptive management is employed to develop projects and to manage the restoration program, especially its goals and objectives.
2. Adaptive management is best suited to large-scale applications.
3. Adaptive management is used to help reduce uncertainty and risk in implementing restoration actions and to increase knowledge about nearshore ecosystems.
4. Adaptive management requires that all restoration actions be viewed, implemented, and monitored as a means to test a hypothesis or answer a question posed by the conceptual model.
5. An adaptive management approach is preferred where data are available at multiple steps and are used to structure a range of alternative response models.
6. Environmental thresholds or triggers are essential in adaptive management.
7. If there are "irreducible uncertainties regarding causal relationships," the Precautionary Principle should be exercised.
8. Adaptive management requires the participation of science, monitoring, and management institutions, including the flexibility to take corrective measures and change an approach based on lessons learned.

Monitoring Principles

Monitoring—defined as "the deliberate and systematic observation, detection, and documentation of conditions, resources, and environmental effects of management and other activities"—must be considered part of an information feedback system called adaptive management, which leads to increased knowledge that in turn reduces uncertainty in decision making and in the outcomes of restoration. As with the restoration and adaptive management principles, we developed a list of important principles based on existing documents recommending monitoring plans and programs:

1. Project objectives should be used to build performance criteria and implement a monitoring program that evaluates attributes directly related to these criteria and the objectives they assess.
2. Restoration actions should test hypotheses or answer specific questions about ecosystem functions and processes and human interventions.
3. Monitoring should determine whether restoration goals are being met.
4. Monitoring must be considered part of an information feedback system called adaptive management that leads to increased knowledge, which in turn reduces uncertainty in decision making and in the outcomes of restoration.
5. Monitoring must be a long-term effort.
6. Monitoring should be interdisciplinary.
7. Monitoring should occur at multiple scales in time and space, and selected indicators must be defined by objectives and be scaled appropriately.
8. Monitoring must be inter-institutional owing to the complex nature of societal management of lands and natural resources.

Introduction

To develop an effective, large-scale ecosystem restoration program for the Puget Sound nearshore—defined as shallow-water environments of estuaries and nearshore marine shorelines—the Nearshore Science Team (NST) of the Puget Sound Nearshore Partnership (PSNP) (formerly known as the Puget Sound Nearshore Ecosystem Restoration Program) has developed a list of guiding restoration principles (GRPs) and fundamental ecological concepts and assumptions. They are called guiding principles as they represent a component of our strategy for restoring the Puget Sound nearshore ecosystem. These principles are considered critical to the success of a broad range of restoration and protection actions and will help establish the geographical and ecological sideboards for the program. These principles, concepts, and assumptions were developed through review of existing scientific and restoration literature. They communicate PSNP's understanding of nearshore ecosystems and provide a framework for identifying, evaluating, and implementing restoration and protection actions. These principles apply to different stages of projects—from early planning to post-implementation monitoring. Developed to inform PSNP, they can also be used by a wide variety of people and organizations involved in restoration and protection of nearshore ecosystems and habitats. This document should be viewed in concert with three other important PSNP-NST products: the guidance document (Fresh et al. 2004), the conceptual model (Simenstad et al. 2004), and the lessons learned (Van Cleve et al. 2004).

Background

The Puget Sound ecosystem is of considerable importance to Washington state, the region, and the nation. Numerous jobs in the state are directly connected to commercial and economic activities occurring on Puget Sound, such as the transshipment of goods and the fishing industries that harvest Puget Sound resources. Many of the goods that pass through Puget Sound ports originate in or are destined for other areas of the United States. People from all over the world come to enjoy Puget Sound; many are drawn by the unique beauty of its natural resources. The quality of life of the millions of citizens who live within a short drive of Puget Sound is positively influenced by the aesthetic amenities and environment provided by this large, complex inland sea.

Puget Sound is a very large, complex system of estuaries that supports tremendous biological productivity in the form of a wide diversity of culturally and economically important species and habitats. With a basin surface area of 39,000 km^2, Puget Sound is influenced by freshwater inputs from 11 major river systems and 10,000 streams, as well as twice-daily tidal ranges of up to 3.7 m at Seattle and 4.6 m at the southern end of the Sound near Olympia. Puget Sound covers an area of 7000 km^2 and includes 4,000 km of shoreline, making it one of the world's largest inland seas. The Puget Sound encompasses five main basins, with an average depth at mean low water of 62.5 m, with a depth range of 91-180 m per basin, to a maximum of 287 m. These extreme depths make Puget Sound one of the deepest water basins in the contiguous United States.

Puget Sound and its adjacent waters support the largest area of remaining estuarine wetlands on the West Coast, exceeding the combined total area of Columbia River and San Francisco Bay estuarine wetlands by over 30%. Because of its size, tidal exchange, and freshwater inputs, Puget Sound supports more than twice the primary productivity of Chesapeake and San Francisco bays combined. The main basin near Seattle is the most productive portion of Puget Sound, supporting primary productivity that exceeds Long Island Sound by more than one-third (Emmett et al. 2000, U.S. Army Corps of Engineers [USACE] 2004). The plankton-rich waters and kelp forests, as well as the macro-algae and eelgrass beds, support a food chain that includes a vast array of fish and wildlife species. Puget Sound is home to at least 7,000 species of invertebrates, 230 fish species, and 70 species of seastars (Washington Department of Natural Resources [WDNR], Washington Department of Fish and Wildlife [WDFW], University of Washington, unpubl. data). Recognizing its uniqueness, the U.S. Environmental Protection Agency (USEPA) designated Puget Sound as an "Estuary of National Significance" in 1988.

Shallow-water environments of Puget Sound estuaries and nearshore marine shorelines (in this document, we collectively refer to these areas as the nearshore) represent the aquatic boundary or interface between freshwater, air, land, and the open waters of Puget Sound. Estuaries include the deltaic portions of river mouths encompassing the upper extent of tidal influence (i.e., tidal freshwater to head of tide) to the outer extent of the delta. By definition, this includes fjord systems such as the major inland passages of Puget Sound that technically constitute an estuarine complex. The nearshore extends inland into the upland to the extent that it directly influences the shoreline, and seaward to the deepest extent of the water column that encompasses the photic zone in adjacent waters (averaging 10-m depth). The nearshore zone also includes backshore and upland areas in which the strongest intertidal upland coupling occurs.

Problem Statement

Impacts to estuarine and nearshore habitats are especially critical because many of the important flora and fauna of Puget Sound depend upon these habitats. One-third of more than 4,000 km of Puget Sound shoreline has been modified by some form of human development, including armoring, dredging, filling, and construction of overwater structures (Puget Sound Water Quality Action Team [PSWQAT] 2002). Uplands adjacent to the tidelands of Puget Sound have been developed, often to the point of eliminating the natural processes that link the uplands to the shoreline. The contamination of water and bottom sediments in parts of Puget Sound has made some fish and shellfish unsafe for human consumption.

Scientists and resource managers believe that these changes to the nearshore habitats of Puget Sound have resulted in significant adverse impacts to critical biological resources. The quantity of estuarine wetlands has declined over 70% throughout Puget Sound and in some areas has been almost entirely eliminated, while over 30% of the marine shorelines have been armored (Bortleson et al. 1980, Levings and Thom 1994, PSWQAT 2002). Twelve species currently listed as federally endangered or threatened under the Endangered Species Act are dependent on the ecosystems of Puget Sound. Listed fish species include Puget Sound chinook salmon (*Oncorhynchus tshawytscha*), Hood Canal chum salmon (*O. kisutch*),

and Puget Sound/Strait of Georgia bull trout (*Salvelinus confluentus*); listed birds include bald eagle (*Haliaeetus leucocephalus*) and marbled murrelet (*Brachyramphus marmoratus*); and listed marine mammals include the Stellar sea lion (*Eumetopias jubatus*) and humpback whale (*Megaptera novaeangliae*). Rapid, unexplained declines in the populations of the southern pod of resident Puget Sound orcas (*Orcinus orca*), groundfish such as cod *(Gadus macrocephalus*), halibut (*Hippoglossus stenolepis*), flounder (*Platichthys stellatus)*, rockfish (S*ebastes spp*.), and various marine birds have recently rallied citizen groups to also seek listing of these species under the Endangered Species Act (PSWQAT 2002, USACE 2004).

Nearshore Restoration Program

The PSNP is a large-scale, multi-phase, comprehensive initiative to protect and restore the natural processes and functions in Puget Sound. The program is constructed around a federal cost-share agreement and partnership between the USACE and the WDFW. This cost-share agreement began as a USACE feasibility study called the Puget Sound Nearshore Ecosystem Restoration Project. Since initiation of the PSNER Project in 2001, the initiative has become more comprehensive, expanding beyond the scope of the original cost-share agreement and resulting in the current Puget Sound Nearshore Partnership. Six federal agencies are active participants and contributors to the program (U.S. Fish and Wildlife Service, U.S. Geological Survey, National Marine Fisheries Service, USEPA, U.S. Navy, in addition to the USACE). Non-federal partners include nine state agencies, tribes, local governments, ports, the shellfish industry, and private citizens.

The first phase of the program is called the feasibility phase, following the USACE water resource planning procedures (USACE 2000). It seeks to accomplish three primary tasks:

1. evaluate significant nearshore ecosystem degradation of Puget Sound;
2. formulate, evaluate, and screen potential solutions to these problems; and
3. recommend a series of actions and projects.

The NST was convened to provide to the program broad scientific guidance. The NST has been charged with developing interdisciplinary, science-based products to organize and guide the program. These products are intended to meet the program goals, and fulfill the feasibility tasks of identifying problems with the nearshore ecosystems of Puget Sound—including determining how people fit into and interact with these ecosystems, establishing major information needs, and finding potential solutions

Program Mission and Goals

The results of the feasibility phase will provide the basis of a plan designed to meet the program mission to "restore and protect the nearshore habitat of Puget Sound for the benefit of the biological resources and the integrity of the ecosystem, and the people that use these resources, including the functions and natural processes of the basin." The restoration plan must be both technically feasible and economically justified.

The following goals have been proposed to guide the program (PSNP 2004):

1. protect and/or restore natural processes that create and maintain Puget Sound nearshore ecosystems, and
2. protect and/or restore ecosystem functions and structures that support valued ecosystem components.

The following strategies will be used to achieve PSNP goals:

1. increase understanding of the natural and social processes and functions of the Puget Sound nearshore, including understanding of human values;
2. connect and integrate PSNP with related restoration and protection efforts;
3. secure funding for implementing the strategic restoration actions; and
4. improve the quality of restoration decision making through active monitoring and adaptive management.

Scope and Limits of Program Actions

The desired intent of all actions under the auspices of this program will be to restore some of the damage done since the settlement of the region by Europeans. The goal is not to restore the ecosystem to pre-settlement condition, but rather to recover, to a significant degree, the lost functions. The desired effect of all actions or studies under this program will be to contribute to the improvement of the nearshore ecosystem of Puget Sound. To accomplish this, the NST will focus on identifying and then repairing degraded ecosystem processes that create and maintain the habitats of Puget Sound.

The NST is focusing on repairing degraded processes because there is little scientific evidence for successful, long-term restoration of habitat structure. Also, only by repairing ecosystem processes can long-term sustainability, with minimal human intervention, be assured (Zedler and Callaway 2001, Zedler et al. 2001, Zedler and Lindig-Cisneros 2001). Restorative measures should reestablish the dynamics of nearshore hydrology, sedimentology, geomorphology, and other habitat-forming processes that naturally create and maintain habitat, rather than simply implant habitat structures. Studies may be recommended that lead to an enhanced understanding of which processes have been most severely degraded.

The geographical extent of the study is defined as the area where program actions are expected to have a response, and will extend downstream from the upstream limits of tidal influence (head of tide) of any river or stream entering Puget Sound, to the western limit of the Strait of Juan de Fuca. It will include all of Puget Sound and the Strait of Georgia north to the United States/Canada border (Figure 1). Within this region, it will include those adjacent uplands that directly affect nearshore processes, and encompass intertidal and subtidal areas to the depth limits of the photic zone (Figure 2).

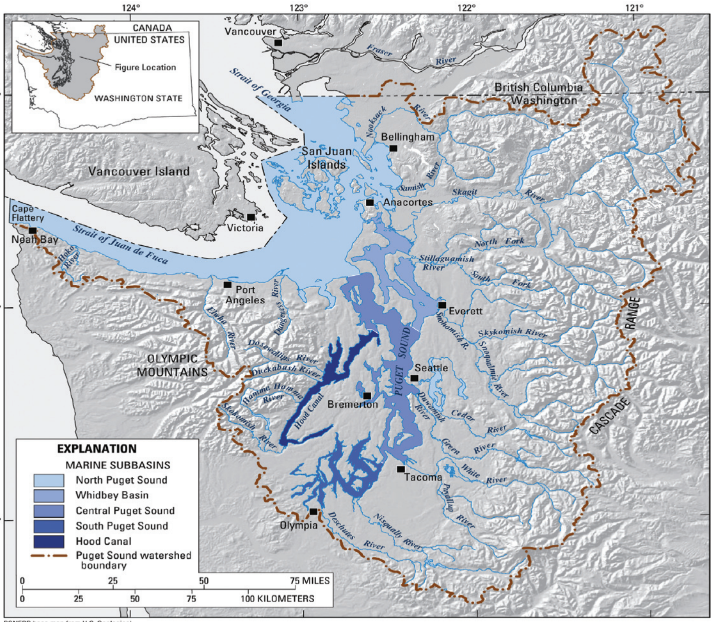

Figure 1. Geographic extent of the Puget Sound Nearshore Partnership (shaded area).

Eroding Bluff - Before Development

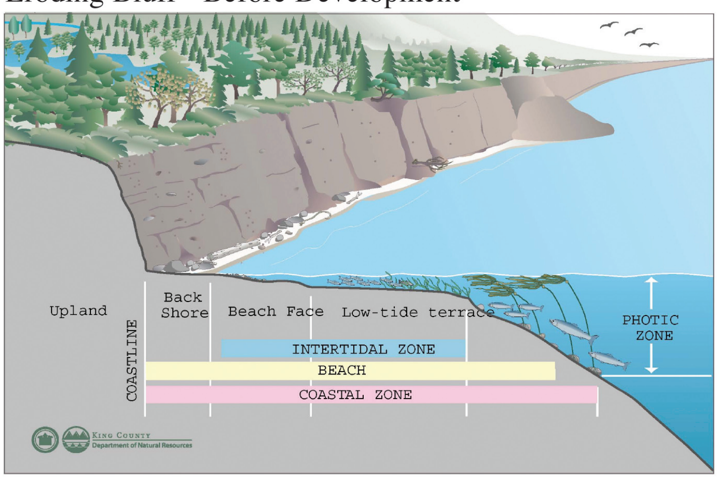

Figure 2. A typical cross-section of the Puget Sound nearshore extends from the top of the adjacent bluff to the head of tide to the limits of the photic zone. Figure courtesy of King County Department of Natural Resources.

Elements of Guiding Restoration Principles Document

One of the first products developed by the NST for PSNP is a set of Guiding Restoration Principles (GRPs). The principles, concepts, and assumptions presented in this document were developed through review of existing scientific and restoration literature. These GRPs will guide all aspects of the program, including providing the context to all actions taken; their planning, design and implementation; and adaptive monitoring and evaluation. The GRPs will set the sideboards, or framework, of what can be studied and where and how protection and restoration actions should take place. The GRPs will focus on ecological concepts critical to nearshore ecosystem restoration and conservation. However, we must recognize the explicit social, political, and economic context of all actions occurring under the program. Clearly, this will require an explicit set of principles for these non-ecological issues. These non-ecological principles will not be covered in this document.

This document comprises four main parts following the introduction. The first section briefly describes the underlying scientific concepts and assumptions upon which the scientific program is organized. The second section presents the GRPs—the framework for a comprehensive, strategic planning process to guide program development and selection of restoration projects in Puget Sound. The third and fourth sections present principles and elements considered essential for adaptive management and monitoring of restoration projects. The principles, concepts, and assumptions set forth in this document are considered a consistent, coherent, and necessary set, which should be understood as a whole to ensure successful program implementation. These principles, while being developed for PSNP, can be used by a wide variety of people and organizations.

Fundamental Concepts and Assumptions

This section briefly describes the underlying scientific concepts and assumptions upon which the PSNP scientific program is organized. These concepts and assumptions summarize the current scientific literature that describes the natural structure and dynamics of estuarine and marine nearshore ecosystems and how we think they will respond to restoration actions.

Because this section addresses only strictly scientific concepts at this point, it does not contain issues found in other sections. For example, in the guiding restoration principles section, we address the following issues:

1. the need to approach nearshore restoration with interdisciplinary science and engineering;
2. the need to understand the effects of anthropogenic disturbances on ecosystem processes; and
3. education and outreach.

A robust body of published literature in the ecological, conservation biology, and restoration sciences underlies the principles and concepts that provide the scientific guidance (see Guiding Restoration Principles) in this document. This body of literature also provides the foundation of the conceptual model (Simenstad et al. 2004). While much of restoration is still treated as paradigms or weakly substantiated theories for some ecosystems, the body of evidence continues to support some fundamental knowledge that can be adopted as basic concepts and assumptions with acceptable scientific uncertainty. Because these assumptions are effectively founded in peer-reviewed scientific literature, the GRPs do not elaborate on sources; rather, they refer the reader to that literature for more detail.

Emergent Properties of Estuarine–Nearshore Ecosystems

Physicochemical processes play a very strong role in organizing and regulating estuarine–nearshore ecosystems

Unlike some ecosystems where ecological structure and processes are strongly dominated by either bottom-up (regulated by primary productivity and related limiting factors, such as nutrients) or top-down (regulated by the effect of organisms at higher trophic levels, principally through predation and competition interactions) organization, estuaries and coastal ecosystems are strongly mediated by physicochemical and other environmental factors. Factors such as river flow, sediment resuspension, and circulation features alter the scope and intensity of responses to both bottom-up (e.g., Boynton and Kemp 2000) and top-down (e.g., Alpine and Cloern 1992) controls on community and food-web structure and production. Physicochemical processes are essential to the maintenance of high-quality, sustainable nearshore ecosystems. Therefore, restoration of these ecosystems will rely just as much, if not more, on restoring these underlying processes as it will on the biotic structure that is the restoration end-point.

The structure of ecosystems is both the consequence of and a factor in the action of system processes that together constitute what are considered ecosystem functions

Strong interactions between ecosystem processes and their physicochemical and biotic structures account for varying levels of ecosystem function. In this case, "function" is defined as the integrated performance or execution of changes within and beyond an ecosystem. Although human cultures may attach certain values to some functions, this definition is intended to be value-neutral. The important concept is that functions of nearshore ecosystems, such as provision of "habitat" that supports fauna, are the manifestations of linkages between processes and structures. As a consequence, the effects of structure on process must be considered equally with the effects of process on structure. Ecosystem functions are also highly integrated. For example, the function of an ecosystem to support characteristic vegetation depends largely on sediment/soil functions. Thus, restoration of a desired ecosystem demands consideration of ecosystem processes and the structure of all interacting components.

Viewing estuarine–nearshore ecosystems in a hierarchical context is important to understanding ecological interactions and processes across different spatial and temporal scales

Complex ecosystems can be viewed as organized across a hierarchy of scales based on boundaries that minimize interaction (O'Neill et al. 1986, 1989). Further, by contrasting different systems across different scales, hierarchies can be used to identify discrete and predictable properties of ecosystems. Scaling issues are particularly relevant to nearshore ecosystems because these systems are typically organized along strong environmental and physiographic gradients within which discrete biotic communities are typically embedded in physicochemical and geomorphic settings. Restoring important ecosystem properties requires an understanding of how information within a nearshore setting can be applied across broader, more complex settings.

Natural disturbance regimes sustain the structure and functions of regional estuarine–nearshore ecosystems

The natural organization of nearshore ecosystems, particularly wetlands, is strongly influenced by dynamic disturbance regimes. Disturbance is considered as "a discrete event in time that disrupts ecosystem, community or population structure and changes resources, substrate availability or the physical environment" (White and Pickett 1985). The combination of climate, geologic setting, tectonic activity, and estuarine (circulation) dynamics in the Pacific Northwest region expose nearshore ecosystems to diverse, periodic and/or intense disturbances. Some of the more important disturbances originate from adjoining watersheds, in the form of flood events, which often combine with storm events to amplify effects at the land margin.

Disturbance regimes are responsible for the complex and dynamic structures of nearshore ecosystems and their functions, including

those that support important biological resources of the region. However, many disturbance regimes have been extensively modified by long-term human alterations or "press events" (Vogl 1980), such as diking and river flow regulation. These are in contrast to "pulse events," which are cyclic or periodic features of natural ecosystems more limited in scope and duration than press events, and are repetitive and part of the natural systems upon which organisms depend (Vogl 1980, Middleton 1999). Attempts to restore nearshore ecosystems that do not recognize natural change, the role of pulse disturbances, and the pervasive effects of press events at the landscape scale will likely fail to achieve the desired sustainable ecosystems (Hobbs and Norton 1996).

Importance of Landscape Setting and Structure

Ecosystem function and performance are contingent upon landscape setting

Understanding the critical role of landscape setting is essential to restoration. The functions of a restored ecosystem will depend largely on the hydrological and geological/topographic characteristics of the system's landscape position (Bedford 1999, Bell et al. 1997, National Research Council 2001). Functions must be addressed at landscape scales. This is especially true where natural ecosystems are highly integrated (e.g., where animals and plant distribution and nutrient flow patterns cross multiple ecosystem boundaries) even though they may change in structure and dynamics along intense environmental gradients, exemplified by nearshore ecosystems. Thus, restoration of important ecosystem functions requires reintegrating landscapes or restorating the functional aspects of landscapes (Risser 1992, Main 1993).

Nearshore ecosystem functions are explainable using concepts from landscape ecology

Landscape ecology examines ecological processes over varying spatial and temporal scales. Landscapes are mosaics of patches, corridors, ecotones, and other elements that can be defined by their structures, functions, and changes (Forman 1995, 1997). Landscape ecology concepts are particularly appropriate to nearshore landscapes. The arrangement and location of interacting segments along strong environmental gradients of salinity, energy, substrates, and organisms exemplify the inherent hierarchical structure of the nearshore (Zonneveld 1990). Similarly, Kneib (1994, 2000) has described such estuarine landscapes as "ecoscapes," with discrete corridors defined by intertidal and shallow subtidal communities, often distinctly stratified by vegetation and substrate.

Similarly, the potentially strong interactions between nearshore ecosystems with uplands and offshore waters fit the concepts of transitional zones, or ecotones, between landscape elements (Naiman and Décamps 1990). These interactions demonstrate the ecological significance of nearshore processes, such as supralittoral drift (Polis and Hurd 1996, Anderson and Polis 1998). Conversely, anthropogenic development of nearshore shorelines alters the integrity and flux of materials and organisms. In many cases in the interconnected landscape, the resilience of plant and animal populations occupying both the connected landscape patches and moving via the corridors can be highly dependent upon asynchronous patch change (Willard and Hiller 1990, Middleton 1999).

Landscape ecology concepts are also useful for linking aquatic resources and land-use management practices (Schlosser 1991). This may be particularly useful for conceptualizing and analyzing ecological restoration (Bell et al. 1997). Structure, function, and change of patches across landscape mosaics affect fundamental ecosystem processes, which determine the trajectories of wetland restoration.

Role of Population Ecology and Life-History Diversity

Spatial and temporal dynamics of animal and plant metapopulations are dependent upon the integrity of nearshore landscapes

There are two dynamics that may be particularly relevant to nearshore ecosystems:

1. metapopulation concepts of spatial structuring and dispersal mechanisms of non-equilibrium populations, and
2. demographic colonization and extinction ("source–sink" dynamics).

These dynamics may be especially relevant because of the complexity of landscape patches, mosaics, and corridors arrayed along the nearshore gradients, and the prominent movement of organisms at different scales across and within the landscape (both directed, as in the case of anadromous fishes, or confined, as in the case of local movements and ontogenetic shifts in estuarine organisms). This immigration–emigration perspective may be particularly important to ecosystem restoration in large (local) scales because plant and animal recruitment to restoring ecosystems may depend upon landscape adjacency and metapopulation dynamics at the landscape level (Orth et al.1994). In a broader perspective, metapopulation concepts have even been used to examine the role of estuaries as metapopulation aggregates of estuarine-dependent (fish) populations, which provide critical sources of coastal populations (Ray 1997).

Metapopulation concepts may need to be better integrated with understanding key processes that influence the persistence of metapopulations (Reiman and Dunham 2000) and incorporate the turnover in landscape patches (Briers and Warren 2000). Nonetheless, metapopulations pose a viable organizing structure to analyzing restoration in the context of dynamic landscapes such as nearshore ecosystems.

Landscape structure is an important factor sustaining life-history diversity within and among populations vulnerable to stochastic ecosystem change

Many coastal plant and animal populations are vulnerable to

unpredictable shifts in ecosystem conditions, both within and beyond the nearshore ecosystems. This is particularly true with anadromous species and populations because their fitness to endure coastal and oceanic variation may often derive from nearshore conditions (Taylor and Bentzen 1993, Thorpe et al. 1998). Reproductive sites are often perceived as critical core areas for preservation and restoration. However, addressing life-history diversity demands consideration of habitat and other requirements at all life-history stages. Developmental transitions also should be considered, particularly landscape structure that optimizes a population/metapopulation's opportunity to maintain or even expand on life-history diversity from a prior developmental stage. A demographic, landscape expression of life-history diversity is particularly germane to nearshore restoration because it addresses the importance of recovering complexity and connectivity of landscape elements. The complex mosaic of landscape elements that originally promoted population (e.g., salmon) resilience forms one important expression of nearshore processes that should be targeted in ecosystem restoration (Lichatowich et al. 1995).

Guiding Restoration Principles

Building on our understanding of the fundamental scientific concepts which drive nearshore ecosystem process, structure, and function, we have developed the following guiding restoration principles to apply this understanding. These guiding principles are anticipated to help define a restoration approach for the NST that will enhance the potential for the PSNP to succeed. These principles draw on ecological restoration literature relevant to the nearshore and on practical guidance that emerges from the lessons of previous restoration efforts. The following set of principles, adapted from several previous works (Restore America's Estuaries and Estuarine Research Federation [RAE/ERF] 1999, Clewell et al. 2000, Society of Wetland Scientists 2000, USEPA 2000, NRC 2001, Streever 2001, WDFW 2001, Fuerstenberg et al. 2002, Simenstad and Bottom 2004), is intended to provide practical guidance for restoration program development.

Strategic

The first set of principles defines an overarching strategy for restoration program development.

Programs should focus on restoration of natural processes that create and maintain nearshore ecosystem structure and function

Guided by this principle, restoration practitioners can avoid the shortfalls of reestablishing habitat structure without those natural processes, and creating habitat types where they did not occur historically. Focusing on restoring underlying ecosystem processes impacted by human use and activities within the nearshore can provide greater long-term project sustainability and an associated reduced need for ongoing maintenance.

Program efforts should promote protection of nearshore habitats and the processes that sustain them

Conservation is considered to be a combination of habitat protection and restoration. Undertaking costly restoration actions without a complementary protective strategy is unlikely to achieve the desired outcome of long-term improvements in ecosystem condition. The conservation strategy should consider the following:

1. protection of key sites of high quality that currently provide a high level of support for nearshore habitat functions;
2. provision of effective corridors between protected and restored sites for the necessary movement of organisms, materials, energy, and genetic information; and
3. protection of restoration sites to ensure their long-term recovery of habitat functions.

Outreach and education should be incorporated into all parts of the program

Public understanding of the ecosystem restoration program is fundamental to its acceptance, support, and, ultimately, its success. A process-based approach to restoration may challenge current paradigms and restoration approaches. We need to improve our understanding of how individual actions impact nearshore ecosystems to promote improved stewardship of these areas and reduce ongoing causes of degradation. Target audiences should include:

1. the general public,
2. elected officials and policy makers, and
3. public and private property owners.

Program efforts must include social, cultural, and economic values at multiple scales in time and space

Just as human behavior, activities, and development patterns have modified and continue to modify nearshore ecosystems, they also have led to protecting and restoring nearshore ecosystems. These behaviors, activities, and development patterns reflect multiple scales in the social, cultural, and economic values of the societies, communities, and individuals that reside, use, or influence nearshore ecosystems over time. Programs geared to restoration and protection of nearshore ecosystems must consider human values, including understanding the motivation for these values and the flexibility and willingness for people to change. Ultimately, program management must be informed by society and must inform society.

Restoration Design

A strategic approach to restoration, which begins with careful design at program and project levels, should be promoted.

Restoration actions should be based on explicitly stated hypotheses

The NST is developing a conceptual model (Simenstad et al. 2004) that provides a framework for organizing our current understanding about the relationship between sediment, water, atmosphere, and biology of nearshore ecosystems. An explicit statement about the anticipated cause and effect of a restoration action helps define objectives that can form the basis for project monitoring, and ultimately advance nearshore science and ecological restoration.

Initial restoration projects should be designed as experiments to address information needs

Serious gaps exist in our understanding of nearshore ecosystem process and the restoration of nearshore habitats. Early actions, carefully designed and implemented, could serve to fill these gaps. On the basis of explicit hypotheses, these actions may improve our understanding of effective restoration actions and contribute to development of a strategic restoration plan with increased potential for success.

Project implementation should be preceded by restoration planning

While early action projects should proceed prior to developing a strategic restoration plan for the Puget Sound nearshore, success of the program will be improved by planning. Strategic restoration planning should be completed at a scale and level of detail sufficient to accomplish the following:

1. account for interactions within and between ecosystems;
2. incorporate relevant landscape ecology concepts;
3. focus program goals at the larger scale of ecosystem recovery, in addition to any site-specific objectives; and
4. restore processes that will impact multiple sites.

Restoration must consider "ecological succession"

The Puget Sound nearshore is a dynamic ecosystem, with physi-

cal, biological, and anthropogenic forces constantly interacting to reshape this "landscape." Our human frame of reference provides only a snapshot of current conditions, and we often fail to perceive the constant change that is occurring. Important concepts of succession in the nearshore include the following aspects:

1. significant change in biological communities for years to decades following a restoration action,
2. perceived success of the restoration action relative to stage of ecological development when evaluated,
3. intermediate stages of elevated productivity that may decrease as the community reaches equilibrium, and
4. a focus on process-based restoration rather than desired, static endpoints.

Project proponents should recognize the limits on ecosystem potential constrained or limited by irreversible change

In some situations it may be necessary to provide partial restoration or mimic lost historical processes or functions. In many cases, it may be difficult to fully understand how a site may have functioned prior to irreversible changes initiated by human activities. Suitable reference sites may help assist in understanding historical site conditions.

Restoration projects should be based on carefully developed goals and objectives. Goals and objectives serve to focus thinking about project proponents, communicate anticipated outcomes to others, and provide a basis for monitoring plan development. To do so, goals and objectives should have the following attributes:

1. clearly stated and specific,
2. measurable,
3. focused on attributes of relevant functions,
4. based on time frames sufficient for recovery of relevant functions or processes or both,
5. measured against appropriate reference sites or standards, and
6. incorporate an understanding of ecological process derived from the conceptual model.

Project Follow-Through

The success of restoration actions is often determined not only by clear planning and good implementation, but by the commitment of project sponsors to post-construction follow-through.

Project objectives should be used to build performance standards and implement a monitoring program that evaluates attributes directly related to these standards and the objectives they assess

Objectives are specific and often quantitative statements about the desired or anticipated outcomes of an action. Performance standards should represent observable or measurable changes, which can be used to determine whether project objectives have been met. Objectives and performance standards should also be specific as to the timeframe over which changes are anticipated.

Adaptive management should be employed in project development and in revising program goals and objectives

Monitoring programs and adaptive management are essential components of effective restoration actions. These concepts are discussed in further detail in the next section. Monitoring of individual projects may reveal flaws in the underlying approach of a restoration program. For instance, specific ecosystem processes may not be restored by a restoration activity, leading to a need to reevaluate the approach of the larger program. Monitoring may provide lessons for changing the approach of projects and programs.

Project proponents should take advantage of best interdisciplinary science and technical knowledge and employ a scientific peer-review process

Much of the science underlying ecosystem restoration is relatively new. Restoration will need to proceed with scientific uncertainty. Using a robust peer-review process may help identify critical flaws in our approach, or alternative hypotheses for observed relationships. Engaging a broader perspective, both cross-discipline and from other geographic regions, will serve to better inform our decisions, and it may reduce uncertainty and risk associated with ecosystem restoration actions.

Analysis of ecosystem processes requires that data represent the spatial and temporal dynamics at various scales as well as being well documented and well defined

Proper data and information management across various ecological scales has been challenging for applied ecological research and environmental planning. When one or more spatial variables are explicitly stated as distinct variables in an analysis, the study becomes a spatial analysis (Meentemeyer and Box 1987). When the spatial configuration and composition (Turner and Gardner 1991) of these variables are distinctly addressed, the study becomes a spatially explicit analysis. Spatially explicit analyses recognize that ecosystems are composed of elements that change over time. The spatial scales at which these elements are recognized and defined, and the temporal scale that corresponds to measured change, are central issues in a line of research that now integrates remote sensing (RS) and geographic information systems (GIS) analysis. These technologies support the measurements of geographic phenomena and processes, the representation of those measurements in a database, and the transformation and operation upon these representations.

Data management lays the foundation for sharing information and supporting decisions in a timely manner. The data management systems typically must coordinate policies, procedures, and standards for data. This includes strategic and tactical plans to store and distribute logical and physical products. Combining access to data in a timely manner with the context and quality of the data is the central goal of an information system (see Batini et al. 1986). Every data element has information that describes the content, quality, condition, and other characteristics of that measurement or observation. The "data about data" is known as metadata. Metadata forms the foundation for any integration between data users, multiple uses of data, error identification and quality control of data, and evaluation of the interpretability of data.[1]

1. See Standard for Digital Geospatial Metadata (FGDC-STD-001-1998 and the National Spatial Data Infrastructure) (Executive Order 12906, 1994. Federal Register 59(71):17671-17674.)

Adaptive Management Principles

The PSNP proposes to take a variety of actions to help improve the condition of the Puget Sound nearshore, including restoring key habitats and processes, identifying important places for protection, studying reference sites, undertaking inventories and assessments, and conducting research to fill key information needs. Because of the large amount of uncertainty associated with restoring nearshore ecosystems, a program goal is to develop an adaptive management and monitoring plan designed to advance our understanding of relationships between ecosystem processes, structure, and functions.

Adaptive management entails using research and monitoring to allow certain projects and activities to proceed despite some uncertainty and risk regarding their consequences (Holling 1978, Walters 1986, Walters and Holling 1990). It recognizes that while we know much about the Puget Sound ecosystem, there is also much that we do not know. Thus, adaptive management emphasizes learning about the affected ecosystem (in this case Puget Sound); in order for us to learn, actions are designed as studies to evaluate ecosystem responses. The overall intent of this process is to reduce the risk and uncertainty associated with future actions.

Adaptive management is employed to develop projects and to manage the restoration program, especially its goals and objectives

Adaptive management should be used at all levels of the program. First, project-specific monitoring should be designed and implemented so that the resulting information can be used to make changes in the existing project. This can be regarded as a form of contingency planning. The goal would be to make changes in an existing project to minimize the risk of doing harm and maximize the ability to meet project goals and objectives. The potential need for post-project corrective measures should be anticipated, and resources should be set aside for this contingency. Where project functional trajectory has been grossly miscalculated, adjusting project objectives should be considered.

Second, adaptive management should be used to design future projects since project monitoring and research will help provide information on what actions are successful. Adaptive management should be employed at as many restored sites as possible so that they continue to move toward desired endpoints and self-sustainability (RAE/ERF 1999).

Third, adaptive management should be used to continually revise and update program goals. Ultimately, the main service by adaptive management is to guide the program.

Adaptive management is best accomplished at large scales

Although adaptive management can be useful for individual project decisions, it is best applied to address programmatic issues, such as refining program goals and objectives, at large scales (e.g., spatially—regional, watershed—and over long time periods).

As stated by the NRC (2004), "Adaptive management may be particularly well-suited to large, complex ecosystem restoration projects (or programs,]sic]), which entail large degrees of risk and uncertainty, multiple and changing objectives, and phased components. Adaptive management can be especially important in multi-phase activities, as it can promote adaptation of ends and means based on lessons learned that lead to model improvements to support future decisions."

Adaptive management is used to help reduce uncertainty and risk in implementing restoration actions and to increase knowledge about nearshore ecosystems

The degraded condition of portions of Puget Sound and the potential for further degradation to occur suggests a compelling need to implement recovery actions as soon as possible. However, our knowledge of what actions should be taken also clearly is limited; thus, the uncertainty and risk associated with most projects will be high. These two concerns can be simultaneously addressed by adaptive management. A fundamental tenet of adaptive management is that we must take action and cannot afford to delay actions until "enough" is known. Carefully targeted restoration activities will be initiated where there is a high amount of certainty in their ecological benefits, risks are low, and needed information will be generated about how to restore the Puget Sound nearshore. These projects can provide the basis for scientific assessments of new technologies, test alternative approaches to restoration, and develop assessment protocols. Adaptive management facilitates using the results of current restoration efforts to design and implement future restoration projects.

Adaptive management requires that all restoration actions be viewed, implemented, and monitored as a means to test hypotheses or answer questions posed by the conceptual model

Adaptive management requires that high-quality information be targeted at specific uncertainties to be successful. This is best accomplished using a conceptual model to identify key questions that can be addressed as part of a project action or research effort. It is essential that management actions be linked to goals (establish causal relationships) through a conceptual model.

An adaptive management approach is preferred where data are available at multiple steps and are used to structure a range of alternative response models

An adaptive management approach is not designed to wait until the end of a project to see if it passed or failed; rather, it is implemented as a series of steps that is fed by information at each step. If necessary, a policy choice is then made that reflects some estimated balance between expected short-term performance and the long-term value of knowing which alternative model (if any) is correct. Thus, adaptive management is most effective where actions are reversible or can be modified iteratively as a function of the system's response.

Environmental thresholds or triggers are essential in adaptive management

Ensuring that adaptive management works requires thresholds or triggers. These must be agreed upon ahead of time, must be measurable, and must be unequivocally linked to cause and goals of the recovery program.

If there are "irreducible uncertainties regarding causal relationships," the Precautionary Principle should be exercised

Too often, decisions about restoration are based upon unfounded optimism despite the inherent high levels of risk and uncertainty in understanding and managing complex ecological systems. The Precautionary Principle states "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically" (Montague 1998). When high risk and uncertainty exist in ecosystem management, the Precautionary Principle should be applied to err on the side of caution (Lackey 2005).

Adaptive management requires the participation of science, monitoring, and management institutions, and the flexibility to take corrective measures and change an approach based on lessons learned

Science and monitoring do not by themselves make an adaptive management process. Rather, management institutions involved (such as PSNP) must be willing and able to use the information to effect changes. In particular, this requires management institutions to be willing to make changes that may be unpopular. Scientists and managers must be willing to accept that some actions will not go as expected and that this is "okay."

Monitoring Principles

Monitoring has been defined as "the deliberate and systematic observation, detection, and documentation of conditions, resources, and environmental effects of management and other activities" (Monitoring Oversight Committee 2002). But as discussed below, it should consist of much more, and in fact, must be considered part of an information feedback system called adaptive management, that leads to increased knowledge that in turn reduces uncertainty in decision making and in the outcomes of restoration (Stober et al. 1996, RAE/ERF 1999, Thom and Wellman 1996, USACE 2002). In fact, Thayer et al. (2003) defined restoration monitoring as follows:

> The systematic collection and analysis of data that provides information useful for measuring project performance at a variety of scales (locally, regionally, and nationally), determining when modification of efforts is necessary, and building long-term public support for habitat protection and restoration.

As with the restoration and adaptive management principles, a number of documents recommending monitoring plans and programs have been developed (Independent Science Panel 2000, Monitoring Oversight Committee 2002, PSWQAT 2002, Thayer et al. 2003, WDNR 1997). From these, we have developed a list of important principles. The intent of the monitoring program is to develop a monitoring plan; the intent of these principles is to guide the plan.

Project objectives should be used to build performance criteria and implement a monitoring program that evaluates attributes directly related to these criteria and the objectives they assess

All restoration projects must have objectives. These objectives, in turn, will be used to create performance criteria for the project. Without objectives and performance criteria, it is impossible to create a meaningful monitoring program. It is insufficient to monitor something just because "monitoring is required." Monitoring must answer the question "Are the objectives and performance criteria being met?"

Restoration actions should test hypotheses or answer specific questions about ecosystem functions and processes and human interventions. Monitoring provides the data to test the hypotheses

Testable hypotheses should be created for each project objective and performance measure. The hypotheses should be stated as a null hypotheses (without project condition) and alternative hypothesis (with project condition). Suitable statistical rigor must be applied to the experimental design and analysis to ensure the validity of the results.

Monitoring should determine whether restoration goals are being met

One means to measure success is to compare the restored site with a reference site. Reference sites are areas that are comparable in process, structure, and function to the proposed restoration site before it was degraded. As such, reference sites may be used as models for restoration projects, as well as a yardstick for measuring the progress of the project through ongoing monitoring (USEPA 2000).

Monitoring must be considered part of an information feedback system called adaptive management that leads to increased knowledge, which, in turn, reduces uncertainty in decision making and in the outcomes of restoration

The results of monitoring should not be considered only as a means of judging the success of meeting project objectives and performance measures—it also must be viewed as a means of furthering the advancement of knowledge, knowledge that can be applied to future projects or used for modifying existing projects. This process will reduce the risk of failure and allow better project design and scoping of expectations for future projects.

Monitoring must be a long-term effort

A successful monitoring program depends on adequate, long-term funding (Spence et al. 1996). Monitoring over the long-term documents trends in ecosystem conditions that occur in response to natural and anthropogenic disturbances, and it allows separation of the effects of human activity from natural variation. The length of the monitoring must also be appropriate to the temporal scale of the ecological responses measured. Cost of monitoring will depend on the degree to which decision makers wish to be certain that management actions are having an anticipated response (Independent Science Panel 2000).

Monitoring should be interdisciplinary.

Monitoring crosses disciplines because ecosystems are complex aggregations of biotic and abiotic components, and the scientists involved in the monitoring represent those areas of ecological expertise. Ecosystems include the human component; therefore, both social and economic sciences need to be included.

Monitoring should occur at multiple scales in time and space and selected indicators must be defined by objectives and be scaled appropriately.

As previously stated in the restoration principles, analysis of ecosystem processes requires that data represent the spatial and temporal dynamics at various scales. Multiple scales of monitoring can measure effects of site- or reach-scale management actions and cumulative effects at larger scales such as watershed, basin, ecoregion, or multiple states. For ecoregional and basin patterns to be evaluated, watershed-scale data must be aggregated to the larger spatial scales. Indicators and monitoring protocols must be measured or conducted in the same way when data are to be combined from different areas, agencies, or times to provide replicability and allow integrated analysis (Spence et al. 1996, Independent Science Panel 2000).

Monitoring must be inter-institutional owing to the complex nature of societal management of lands and natural resources

Monitoring becomes inter-institutional because lands are held by many different institutions, both public and private, and because many agencies have regulatory and management missions that directly or indirectly relate to salmonid conservation.

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PSNERP and the Nearshore Partnership

The **Puget Sound Nearshore Ecosystem Restoration Project** (PSNERP) was formally initiated as a General Investigation (GI) Feasibility Study in September 2001 through a cost-share agreement between the U.S. Army Corps of Engineers and the State of Washington, represented by the Washington Department of Fish and Wildlife. This agreement describes our joint interests and responsibilities to complete a feasibility study to

> "…*evaluate significant ecosystem degradation in the Puget Sound Basin; to formulate, evaluate, and screen potential solutions to these problems; and to recommend a series of actions and projects that have a federal interest and are supported by a local entity willing to provide the necessary items of local cooperation.*"

The current Work Plan describing our approach to completing this study can be found at:

http://pugetsoundnearshore.org/documents/StrategicWorkPlanfinal.pdf

Since that time, PSNERP has attracted considerable attention and support from a diverse group of individuals and organizations interested and involved in improving the health of Puget Sound nearshore ecosystems and the biological, cultural, and economic resources they support. The **Puget Sound Nearshore Partnership** is the name we have chosen to describe this growing and diverse group, and the work we will collectively undertake that ultimately supports the goals of PSNERP, but is beyond the scope of the GI Study. Collaborating with the Puget Sound Action Team, the Nearshore Partnership seeks to implement portions of their Work Plan pertaining to nearshore habitat restoration issues. We understand that the mission of PSNERP remains at the core of our partnership. However restoration projects, information transfer, scientific studies, and other activities can and should occur to advance our understanding, and ultimately, the health of the Puget Sound nearshore beyond the original focus and scope of the ongoing GI Study. As of the date of publication for this Technical Report, our partnership includes participation by the following entities:

Interagency Committee for Outdoor Recreation

King Conservation District

King County

National Wildlife Federation

NOAA Fisheries

Northwest Indian Fisheries Commission

People for Puget Sound

Pierce County

Puget Sound Action Team

Salmon Recovery Funding Board

Taylor Shellfish Company

The Nature Conservancy

U.S. Army Corps of Engineers

U.S. Environmental Protection Agency

U.S. Geological Survey

U.S. Fish and Wildlife Service

University of Washington

Washington Department of Ecology

Washington Department of Fish and Wildlife

Washington Department of Natural Resources

Washington Public Ports Association

Washington Sea Grant

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PUGET SOUND NEARSHORE PARTNERSHIP

RESTORING OUR ECOSYSTEM HEALTH